OPAL-RT

# OP5600 HILBOX USER GUIDE

## Real-Time Simulator

WWW.OPAL-RT.COM

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# SYMBOL DEFINITIONS

The following table lists the symbols used in this document to denote certain conditions:

| Symbol | Definition |
|---|---|
| | ATTENTION: Identifies information that requires special consideration |
| | TIP: Identifies advice or hints for the user, often in terms of performing a task |
| | REFERENCE _ INTERNAL: Identifies an additional source of information within the bookset. |
| **CAUTION** | Indicates a situation which, if not avoided, may result in equipment or work (data) on the system being damaged or lost, or may result in the inability to properly operate the process. |
| | Indicates a situation where users must observe precautions for handling electrostatic sensitive devices. |
| | CAUTION: Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. |
| | WARNING: Indicates a potentially hazardous situation which, if not avoided, could result in serious injury or death. |

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# OP5600 SIMULATOR

## INTRODUCTION

The OP5600 is a complete simulation system capable of operating with either Spartan 3 or Virtex 6 FPGA platforms. It is designed to be used either as a desktop (or shelf top) or as a more traditional rack mount. It contains a powerful Target Computer and a flexible, high-speed Front End Processor and a signal conditioning stage. The new design makes it easier to use with standard connectors (DB37, RJ45 and mini-BNC) without the need for input/output adaptors and allows quick connections for monitoring.

The front of the chassis provides the monitoring interfaces and monitoring connectors, while the back of the chassis provides access to the FPGA monitoring connections, all I/O connectors, power cable and main power switch.

Inside, the main housing is divided into two sections, each with a specific purpose and connected only by a DC power cable and a PCIe cable:

In its standard configuration, the lower part of the chassis contains a powerful target computer that can be added to a network of simulators or can act as a standalone. The target computer includes the following features:

- ATX motherboard with up to 12 cores
- 6 DRAM connectors
- 250 Mb hard disk
- 600 W power supply
- PCIe boards (up to 8 slots, depending on the configuration).

The upper section contains the conditioning modules and a high speed Front-End Processor (this includes the DC supplies used for analog and digital signals). The upper section includes the following devices:

- Flat carrier capable of connecting up to 8 mezzanine boards, depending on the configuration
- Type B mezzanine boards are available in several types, including (but not limited to):
  - OP5353, 32 digital inputs
  - OP5354, 32 digital outputs
  - OP5330, 16 analog inputs
  - OP5340, 16 analog outputs
- Front-End processor (Spartan or Virtex) able to process conditioning signals and execute fast models previously downloaded through the PCIe link. This PCIe link is used to transmit and receive data between the target and the front-end processor.

# SIMULATOR ARCHITECTURE

## CONFIGURATION OPTIONS

The OP5600 is available in a number of different configurations that make it easier to integrate into your environment:

| Platform | Option 1 | Option 2* | Option 3** |
|---|---|---|---|
| Spartan 3 (OP5142) | With target computer configuration (2.4 or 3.3 GHz), up to 12 cores **(Standard)** See Figure 1 | Without target computer. With external PCIe Extender cable x1 | Without target computer. With PCIe fiber optic remote |
| Virtex 6 (ML605) | With target computer configuration (2.4 or 3.3 GHz), up to 12 cores | Without target computer. With external PCIe Extender cable x8 | Without target computer. With PCIe fiber optic remote |

The following images illustrate the simulator's architecture for each option using assembly views of the simulation hardware components within the OP5600 chassis.

* Option 2 is designed for use with a maximum cable length of 2m.

** Option 3 is designed for use with a maximum fiber optic cable length of 2 Km.

### Simulator Architecture Example

The example shown is only to illustrate how the OP5600 is assembled. OPAL-RT strictly prohibits users from opening the OP5600. Opening the unit will render the warranty null and void.

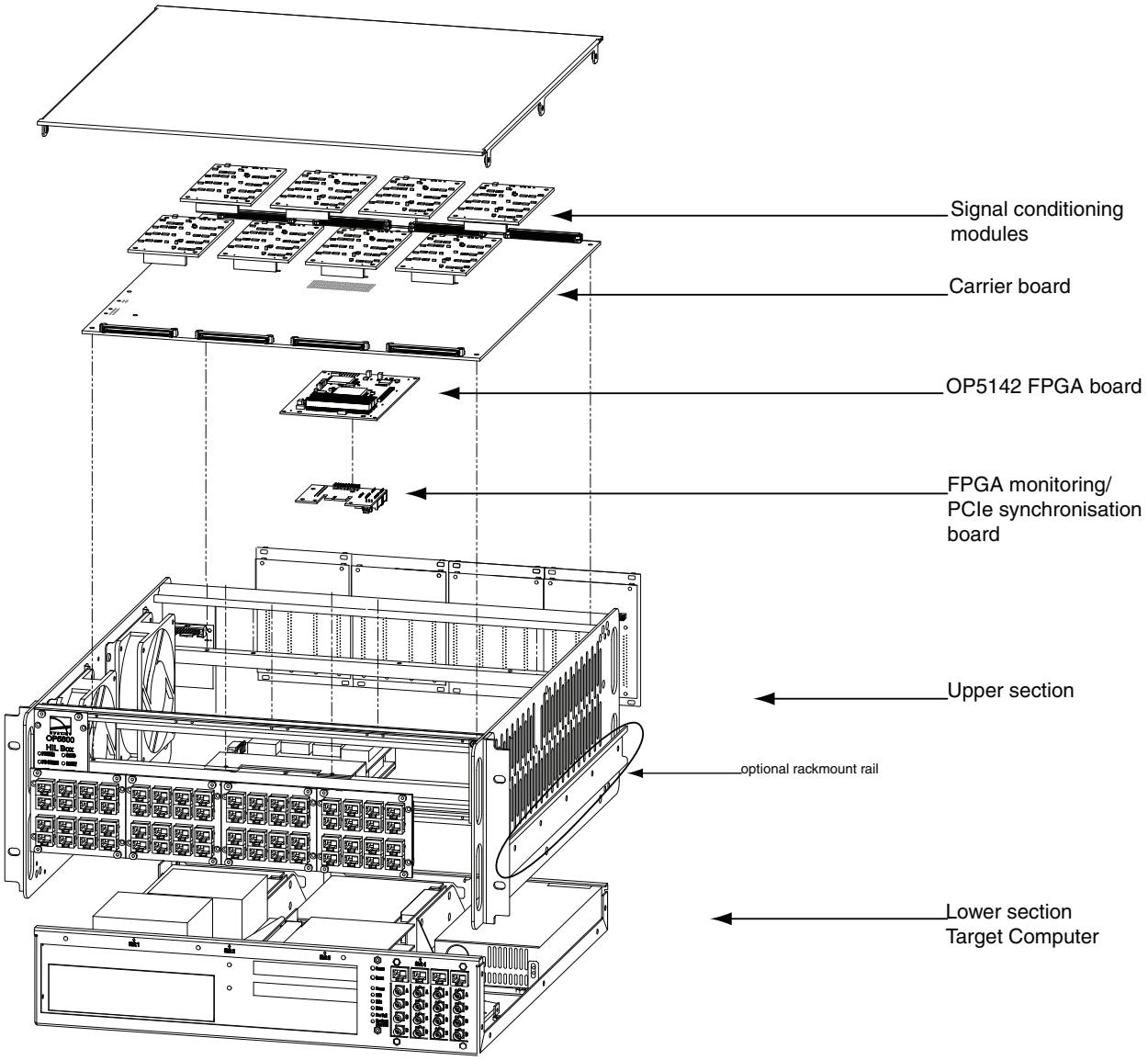



Figure 1: OP5600 with Spartan 3 and target computer

# RECEIVING AND VERIFICATION

After opening the package, remove the equipment and components. Make sure that all the items described in “standard hardware” are actually in the box and are undamaged.

## STANDARD HARDWARE

The OP5600 Real-Time Simulator includes the following basic hardware:

| Item | Description | Part Number |
|---|---|---|
| OP5600 simulator | Complete simulator with either QNX or Redhat O/S | N/A |
| System Integration binder | RT-LAB software CD<br>O/S CD (Redhat or QNX)<br>Documentation CD | N/A |
| Mini-BNC cables (4) | 2 m (6 ft 6”) adapter cables for mini-BNC to BNC. 75 Ohms simplex | MBBN1PP-3 |
| RJ45 cables (4) | 61cm (24”) RJ45 cables | C-02B-CAT6 |
| DB37M breakout board | Provides extended space for connections | BRKSD37M-R |
| Dual row breakout board | Provides extended space for connections | BRK2X20 |
| Flat cable | IDC 40 pin IDC cable | CPWLS4104 |
| Power cable | 1.83 m (6’) power cord, black (10A 125V) | CPC06 |

**OPAL-RT strongly recommends the use of anti-static wrist straps whenever handling any electronic device provided by OPAL-RT. Damage resulting from electrostatic charges will not be covered by the manufacturer’s warranty.**

## INSTALLATION AND CONFIGURATION

The new design means that installation is simply a matter of placing the chassis on a shelf or a desktop, or inserting it into a traditional rack and connecting the cables.

If the system is configured with the Virtex 6, ML605 FPGA board, there is a maximum of 6 signal conditioning mezzanines (these will be in groups 1, 2 and 4 on the carrier board).

If the system is configured with the Spartan 3, OP5142 signal conditioning board, there is maximum of eight mezzanines allowed.

# HARDWARE CONFIGURATION

The interfaces provided on the OP5600 simulator may vary depending on the system configuration selected, Virtex 6 (ML605) or Spartan 3 (OP5142).

## SPARTAN 3 (OP5142) CONFIGURATION

### Front Connectors

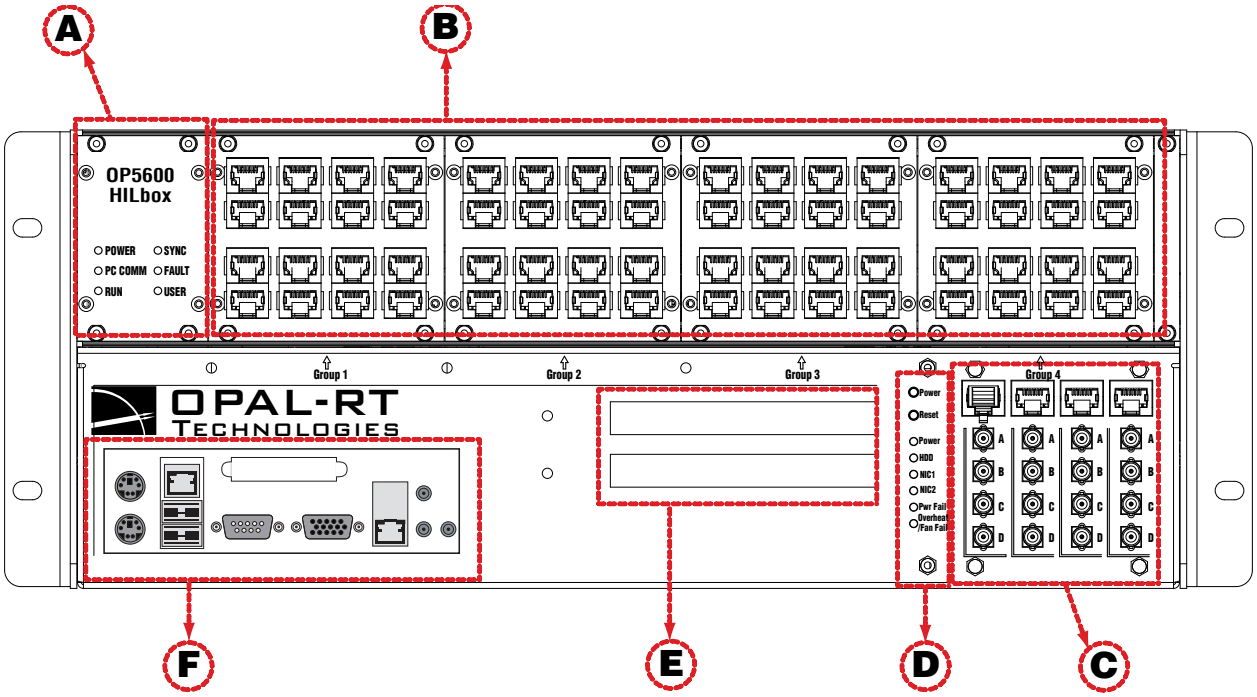



Figure 2: OP5600 front connector panels (Spartan 3)

A. Inactive section. These functions are currently in development and unavailable.

B. 4 panels of RJ45 connectors provide connections to monitor output from mezzanine I/O boards. Each connector is linked to front and back mezzanines on the carrier board. Analog mezzanines (channels 0-15) will use only the first column of connectors. Digital mezzanines will use both columns (channels 0-15 in the first column and channels 16-31 on the second column of connectors). See “DB37F Connections” and “RJ45 connections” for more detailed information.

C. Monitoring RJ45 connectors with mini-BNC terminals: RJ45 cables connect from a channel on an RJ45 panel (B) to one of four RJ45 monitoring connectors (C). Mini-BNC connectors allow for quick cable connections to monitoring devices (such as an oscilloscope). See “connecting monitoring devices” for details.

D. Target computer monitoring interface. Two push buttons include POWER in top position to start the target computer and RESET in the bottom position to reset the target computer. There are 6 LED indicators:

| LED | NAME | Description |
|---|---|---|
| Green | Power | On indicates that the unit is powered up. |
| Green | HDD | On indicates that the hard disk drive is operating. |
| Green | NIC1 | On indicates that network port 1 is in use. |
| Green | NIC2 | On indicates that network port 2 is in use. |
| Red | Power Fail | On indicates a power fault. |
| Red | Overheat/Fan Fail | On indicates either that unit has overheated or a fan fault. |

E. Optional PCI or PCIe connector slots (by default, these spaces will be covered by blank plates if there are no optional PCI cards. If there are PCI cards installed, the spaces will contain the PCI connectors).

F. Standard computer connectors (left to right): mouse and keyboard, USB ports, monitor, network ports. Although use of these connectors is optional but not required to use the OP5600, one network port is required for network connection.

## VIRTEX 6 (ML605) CONFIGURATION

The Virtex 6 monitoring interface is nearly identical to the Spartan 3, with RJ45 monitoring panels.

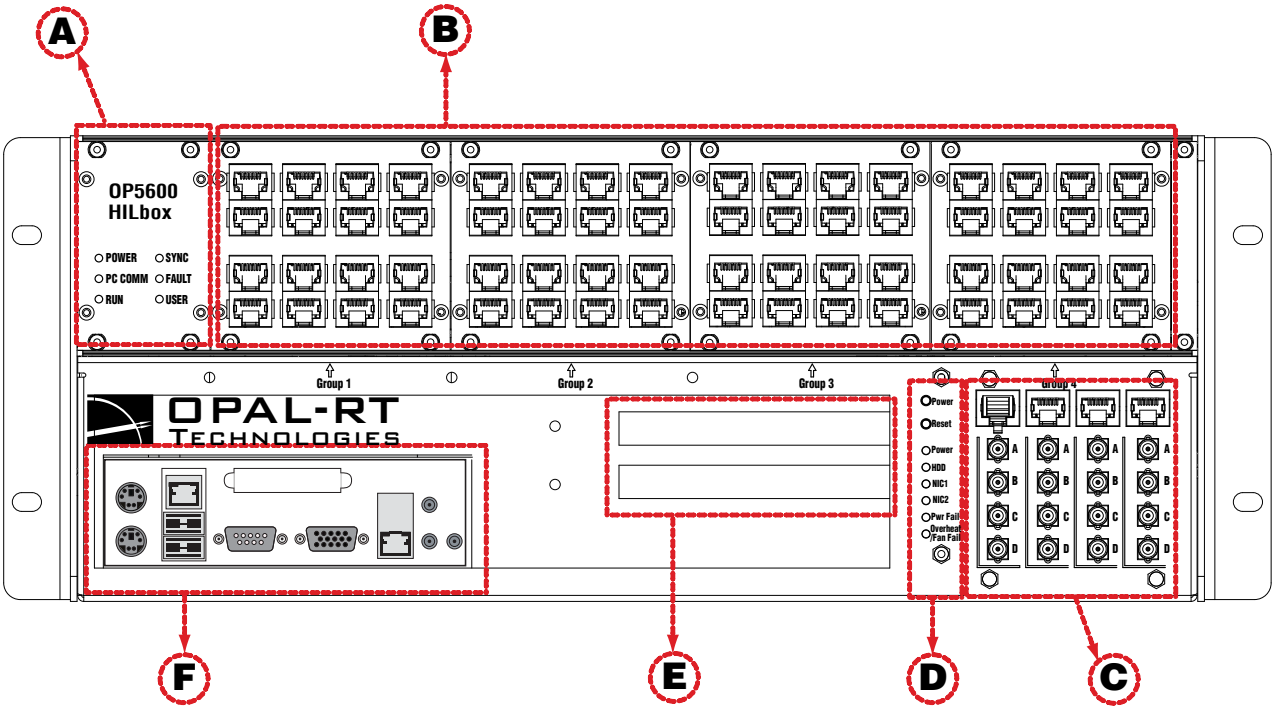



Figure 3: OP5600 front connector panels (Virtex 6)

A. Inactive section. These functions are currently unavailable.

B. 3 panels of RJ45 connectors provide connections to monitor output from mezzanine I/O boards. Each connector is linked to front and back mezzanines on the carrier board. Analog mezzanines (channels 0-16) will use only the first column of connectors. Digital mezzanines will use both columns (channels 0-15 in the first column and channels 16-31 on the second column of connectors). See the mezzanines connector image and the RJ45 pinouts for more detailed information.

C. Monitoring RJ45 connectors with mini-BNC terminals: RJ45 cables connect from a channel on an RJ45 panel (B) to one of four RJ45 monitoring connectors (C). Mini-BNC connectors allow for quick cable connections to monitoring devices (such as an oscilloscope). See “connecting monitoring devices” for details.

D. Target computer monitoring interface. Two push buttons include POWER in top position to start the Target computer and RESET in the bottom position to reset the Target computer. There are 6 LED indicators:

| LED | NAME | Description |
|---|---|---|
| Green | Power | On indicates that the unit is powered up. |
| Green | HDD | On indicates that the hard disk drive is operating. |
| Green | NIC1 | On indicates that network port 1 is in use. |
| Green | NIC2 | On indicates that network port 2 is in use. |
| Red | Power Fail | On indicates a power fault. |
| Red | Overheat/Fan Fail | On indicates either that unit has overheated or a fan fault. |

E. Optional PCI or PCIe connector slots (by default, these spaces will be covered by blank plates if there are no optional PCI cards. If there are PCI cards installed, the spaces will contain the PCI connectors).

F. Standard computer connectors (left to right): mouse and keyboard, USB ports, monitor, network ports. Although use of these connectors is optional but not required to use the OP5600, one network port is required for network connection.

## BACK CONNECTORS

The back connectors are the same, regardless of the selected configuration option.

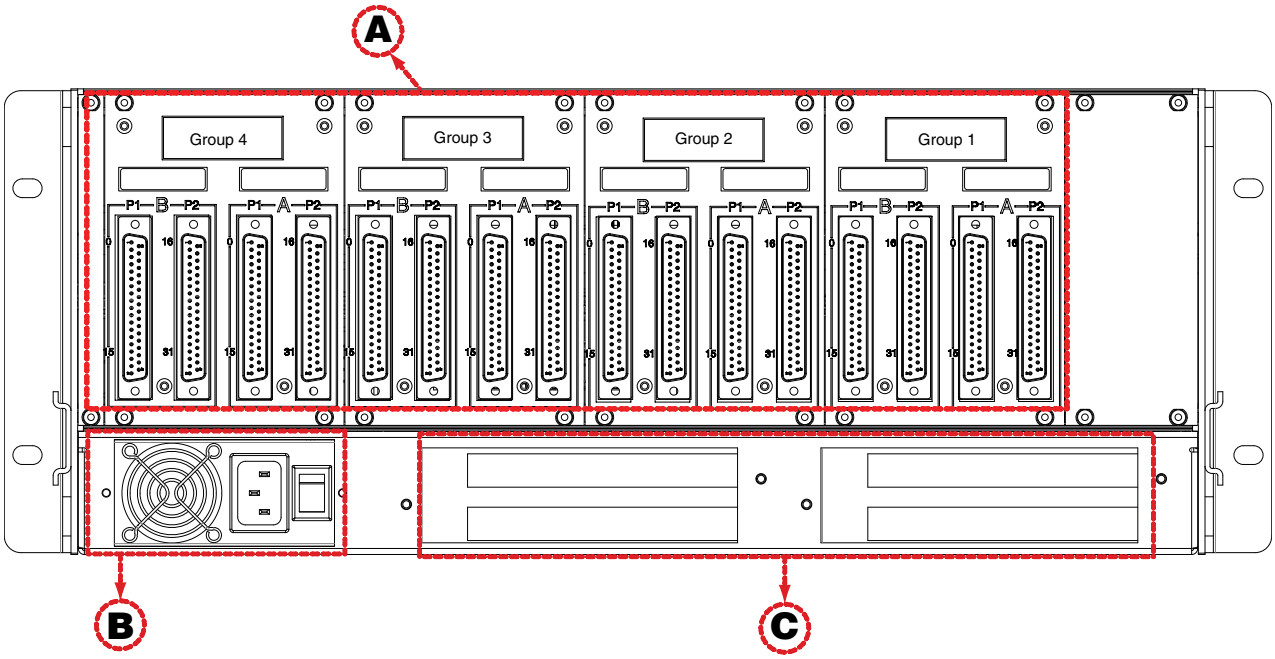



Figure 4: OP5600 rear connector panels

A. DB37F I/O connectors (see “Table 1: Pin Assignments” for more details). The image (opposite) illustrates the links between the mezzanines and the DB37 I/O connectors
B. Power connector and power On/Off switch
C. Optional PCI or PCIe connector slots.

# DB37F CONNECTIONS

Each pair of mezzanines (A & B) is linked to four female DB37 connectors (I/Os) on the back of the chassis:

The first two connectors (left to right) represent channels from Group B, which are linked to the conditioned channels from the **back** mezzanine. The last two connectors (left to right) represent channels from Group A, which are linked to the conditioned channels from the **front** mezzanine.

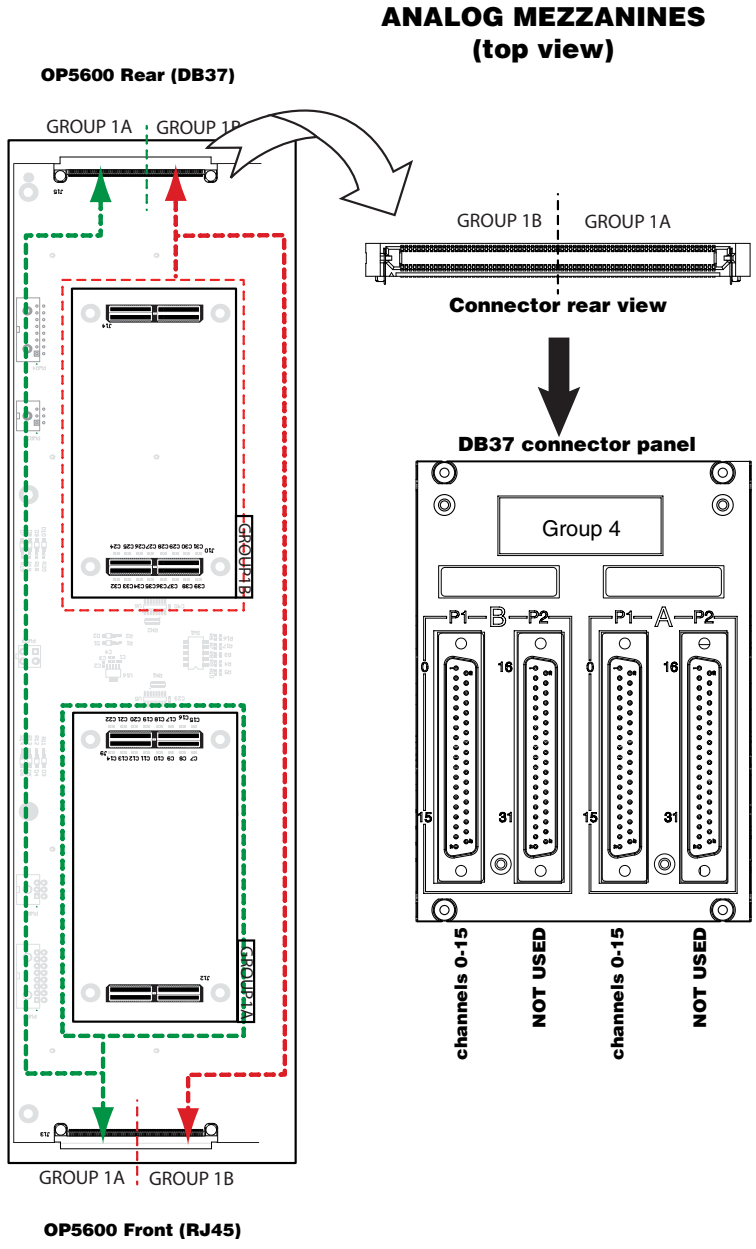



Figure 5: DB37 connection to mezzanines

If the front mezzanine is an analog module (DAC or ADC), the 16 channels are on connector A, P1 and P2 does not carry any signals.

If the back mezzanine is an analog module (DAC or ADC), the 16 channels are on connector B, P1. P2 does not carry any signals.

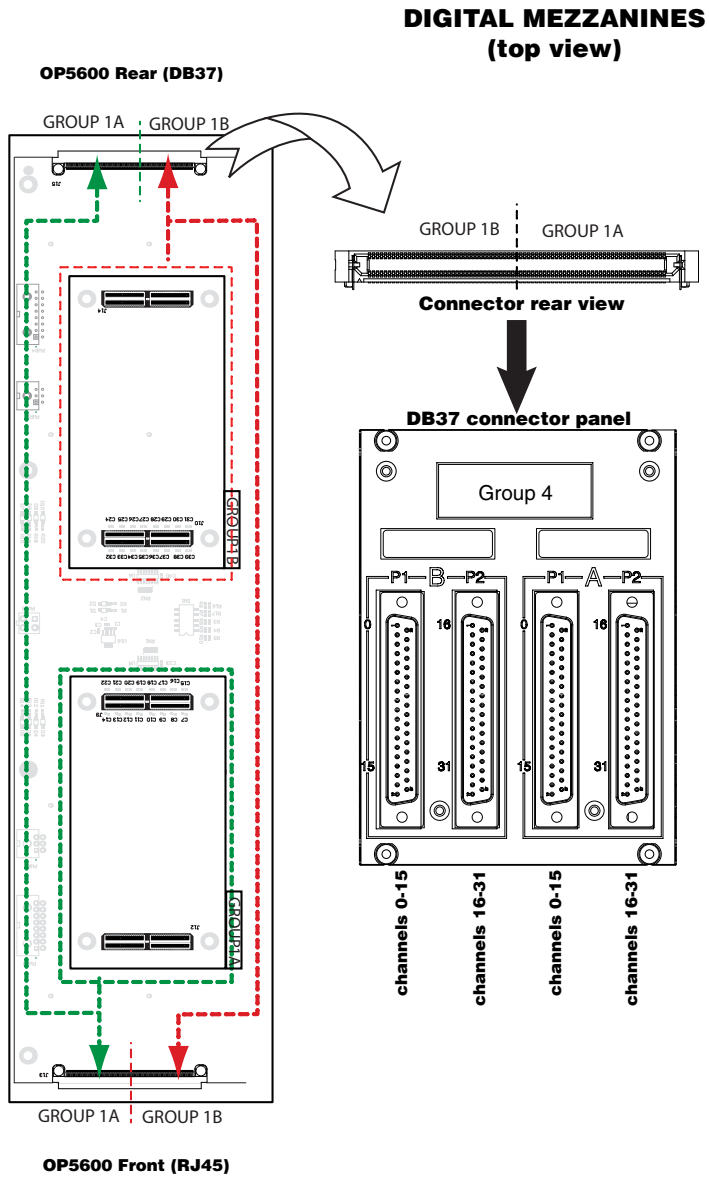



Figure 6: DB37 connection to mezzanines

If the front mezzanine is a digital module (Din or Dout), the first 16 channels (00 to 15) are on the connector A, P1and the next 16 channels (16 to 31) are on the A, P2.

If the back mezzanine is a digital module (Din or Dout), the first 16 channels (00 to 15) are on the connector B, P1 and the next 16 channels (16 to 31) are on the B, P2.

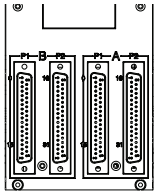
All signals are represented by a positive-negative pair that are always available on the connector pins, for example: for channel 08 : (08+, -08)

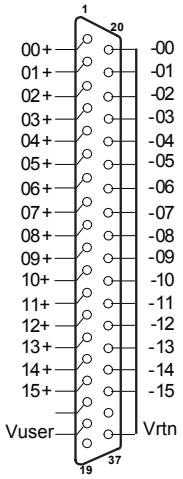
INTERFACE:

- For a single-ended output, the negative conductor is connected to Ground.
- For a differential output, the positive and negative signals are on the connector.
- For a differential input, the connection must be between the positive/negative pair.
- If the input is singled-ended, user's ground must be connected to the negative side of the pair.

# OP5600 DB37 PIN ASSIGNMENTS

| Connector A Ch. 0-15 | | | | Connector A Ch. 16-31 | | | |
|---|---|---|---|---|---|---|---|
| **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** |
| 1 | +CH00 | 20 | -CH00 | 1 | +CH16 | 20 | -CH16 |
| 2 | +CH01 | 21 | -CH01 | 2 | +CH17 | 21 | -CH17 |
| 3 | +CH02 | 22 | -CH02 | 3 | +CH08 | 22 | -CH18 |
| 4 | +CH03 | 23 | -CH03 | 4 | +CH19 | 23 | -CH19 |
| 5 | +CH04 | 24 | -CH04 | 5 | +CH20 | 24 | -CH20 |
| 6 | +CH05 | 25 | -CH05 | 6 | +CH21 | 25 | -CH21 |
| 7 | +CH06 | 26 | -CH06 | 7 | +CH22 | 26 | -CH22 |
| 7 | +CH07 | 27 | -CH07 | 7 | +CH23 | 27 | -CH23 |
| 9 | +CH08 | 28 | -CH08 | 9 | +CH24 | 28 | -CH24 |
| 10 | +CH09 | 29 | -CH09 | 10 | +CH25 | 29 | -CH25 |
| 11 | +CH10 | 30 | -CH10 | 11 | +CH26 | 30 | -CH26 |
| 12 | +CH11 | 31 | -CH11 | 12 | +CH27 | 31 | -CH27 |
| 13 | +CH12 | 32 | -CH12 | 13 | +CH28 | 32 | -CH28 |
| 14 | +CH13 | 33 | -CH13 | 14 | +CH29 | 33 | -CH29 |
| 15 | +CH14 | 34 | -CH14 | 15 | +CH30 | 34 | -CH30 |
| 16 | +CH15 | 35 | -CH15 | 16 | +CH31 | 35 | -CH31 |
| 17 | | 36 | | 17 | | 36 | |
| 18 | Vuser 1 A* | 37 | Vrtn 1 A* | 18 | Vuser 2 A* | 37 | Vrtn 2 A* |
| 19 | | | | 19 | | | |






| Connector B Ch. 0-15 | | | | Connector B Ch. 16-31 | | | |
|---|---|---|---|---|---|---|---|
| **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** | **DB37** | **Module pin assignment** |
| 1 | +CH00 | 20 | -CH00 | 1 | +CH16 | 20 | -CH16 |
| 2 | +CH01 | 21 | -CH01 | 2 | +CH17 | 21 | -CH17 |
| 3 | +CH02 | 22 | -CH02 | 3 | +CH08 | 22 | -CH18 |
| 4 | +CH03 | 23 | -CH03 | 4 | +CH19 | 23 | -CH19 |
| 5 | +CH04 | 24 | -CH04 | 5 | +CH20 | 24 | -CH20 |
| 6 | +CH05 | 25 | -CH05 | 6 | +CH21 | 25 | -CH21 |
| 7 | +CH06 | 26 | -CH06 | 7 | +CH22 | 26 | -CH22 |
| 7 | +CH07 | 27 | -CH07 | 7 | +CH23 | 27 | -CH23 |
| 9 | +CH08 | 28 | -CH08 | 9 | +CH24 | 28 | -CH24 |
| 10 | +CH09 | 29 | -CH09 | 10 | +CH25 | 29 | -CH25 |
| 11 | +CH10 | 30 | -CH10 | 11 | +CH26 | 30 | -CH26 |
| 12 | +CH11 | 31 | -CH11 | 12 | +CH27 | 31 | -CH27 |
| 13 | +CH12 | 32 | -CH12 | 13 | +CH28 | 32 | -CH28 |
| 14 | +CH13 | 33 | -CH13 | 14 | +CH29 | 33 | -CH29 |
| 15 | +CH14 | 34 | -CH14 | 15 | +CH30 | 34 | -CH30 |
| 16 | +CH15 | 35 | -CH15 | 16 | +CH31 | 35 | -CH31 |
| 17 | | 36 | | 17 | | 36 | |
| 18 | Vuser 1 B* | 37 | Vrtn 1 B* | 18 | Vuser 2 B* | 37 | Vrtn 2 B* |
| 19 | | | | 19 | | | |

Table 1: Pin Assignments

*Vuser is available on Dout only.

# RJ45 CONNECTIONS

Each RJ45 monitoring panel on the front of the OP5600 simulator connects to front and back mezzanines. The following images illustrate how the mezzanines are linked to the connectors.

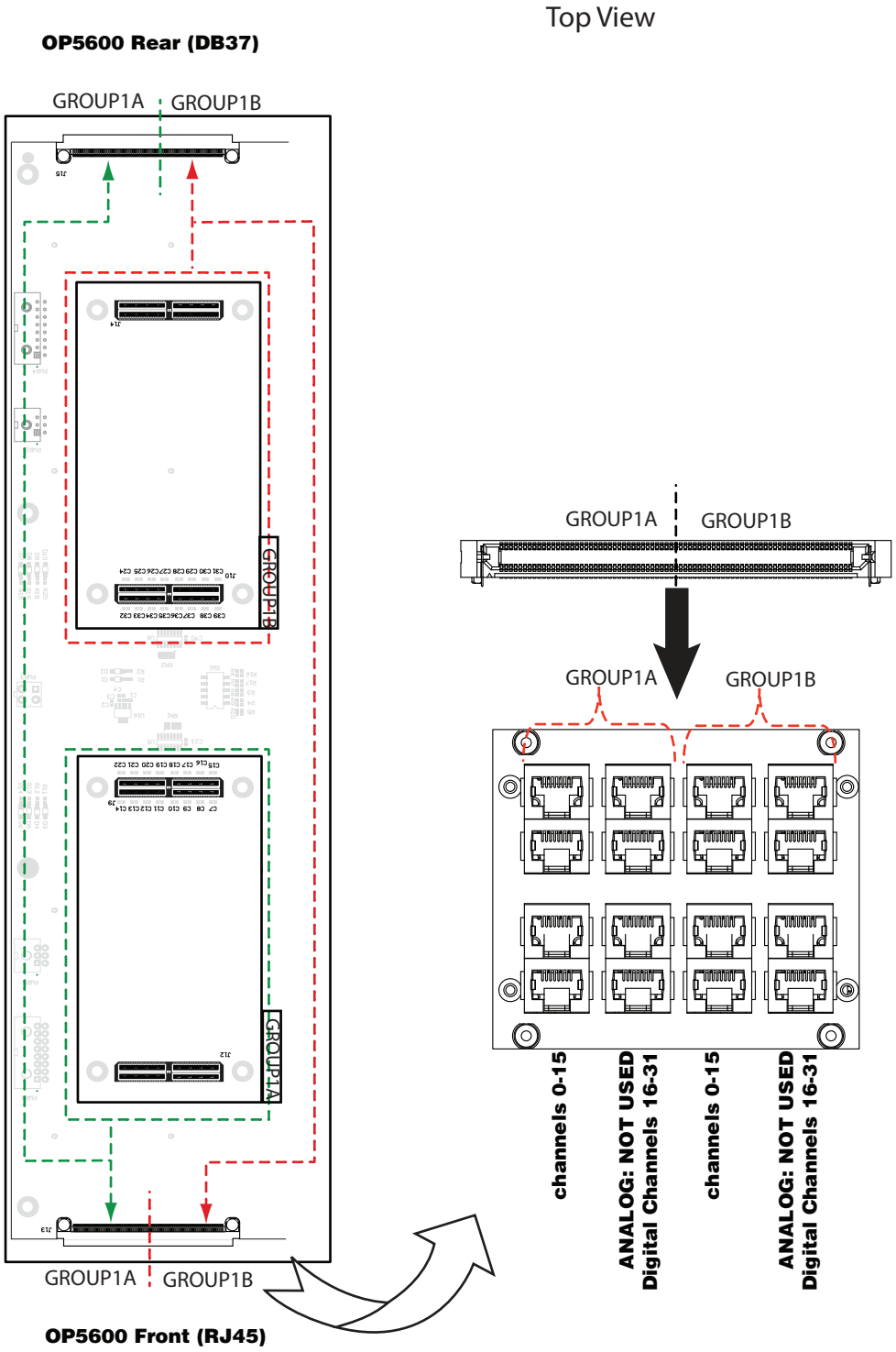



Figure 7: RJ45 connection to mezzanines

# RJ45 CHANNEL ASSIGNMENTS

Each mezzanine is assigned two columns of RJ45 connectors. Each column represents a series of channels, divided into 4 channels per jack, as shown in Figure 8.

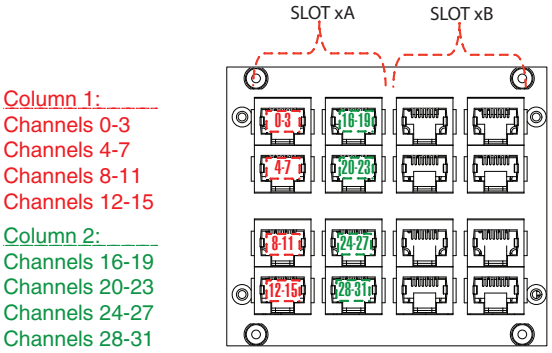



Figure 8: RJ45 channel assignments

## CONNECTING MONITORING DEVICES

The OP5600 simulator offers quick, single-ended connections, through RJ45 and mini BNC connectors, to any monitoring device (i.e. oscilloscope, etc.). These mini-BNC jacks let you monitor 4 channels individually. Simply follow these instructions (as illustrated in Figure 9):

**CAUTION**

**The monitoring board has a gain of 0.1 to allow higher signals to be read. Oscilloscopes must be adjusted with a gain of 10 to compensate and ensure a better reading.**

**Only connect RJ45 cables from upper section (A) monitoring jacks to lower section monitoring panel (B, as shown). Connecting any other cable or device may result in damage to the equipment.**

**The network cable must only be connected to the standard computer connector network jack (see page 12). DO NOT connect the network cable in any jack other than the jack intended for that purpose.**

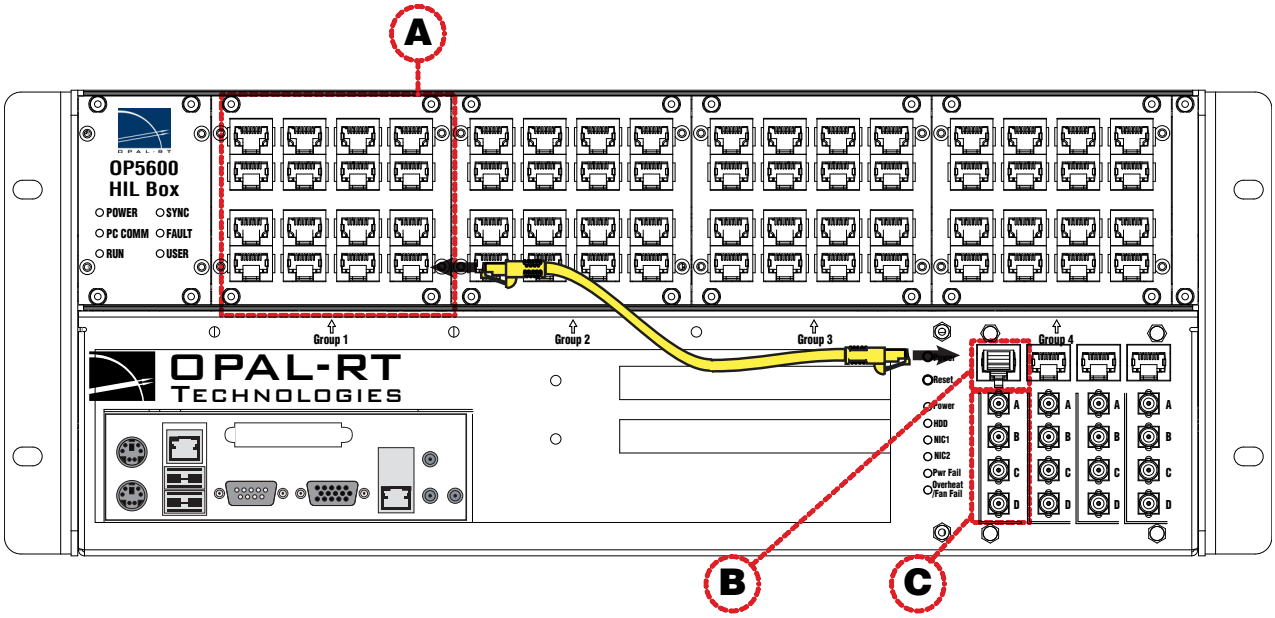



Figure 9: How to connect cables for monitoring

1. Connect one end of the RJ45 cable to the desired channels (A). See Figure 8 for RJ45 connector pinouts
2. Connect the other end of the RJ45 cable to the monitoring connector (B)
3. Connect a mini-BNC cable to each BNC jack (C) and connect the other end of the cable to the desired monitoring device. The mini-BNC jacks each connect to one of the 4 channels of the RJ45 Connector (A). In the example shown in Figure 8, the RJ45 cable is connected to channels 28-31. The mini-BNC cable jacks, identified as A, B, C, D, represent each channel in the following order;
   A = channel 28,
   B = channel 29,
   C = channel 30
   D = channel 31.

# OP5330 DIGITAL TO ANALOG CONVERTER

## DESCRIPTION

The OP5330 digital to analog converter (DAC) provides 16 single-ended digital output channels. Each channel uses a 16-bit resolution digital-to-analog converter. It is a part of the OP5000 series of optional modules for OPAL-RT's state of the art HIL (hardware-in-the-loop) systems, intended for use with OPAL-RT carrier boards (OP5130, OP5220, OP5222, OP5600, OP6228).

Each OP5330 can sample up to 1 MS/s, giving a total throughput of 8 MS/s, all channels are simultaneously sampled. The onboard EEPROM provides offset and gain data adjustment written during the calibration process, as well as over-voltage protection.

By default, the maximum output signal is set to ±16 volts.

#### REQUIREMENTS

**Software**

- RT-LAB 8.4.0 and higher

**Hardware**

- OPAL-RT simulator:
  - OP5600 series simulator
  - OP5000 series of hardware-in-the-loop simulators
  - OPAL-RT I/O expansion box (only for use with OPAL-RT simulators)
- OPAL-RT carrier board:
  - OP5130, OP5220, OP5222, OP5600, OP6228

#### FEATURES

- 16 single-ended analog output channels
- All outputs are sampled simultaneously at up to 1 MS/s
- 16 bit resolution
- ±15 V voltage range output
- ±15 mA maximum current per channel

#### OFFSET AND GAIN CALIBRATION

The OP5330 contains a serial EEPROM to store the module identification, calibration information and other important information. Each OP5330 is factory calibrated after assembly; during calibration, gain and offset are adjusted to ensure accurate target output values at ±20 mV noise and offset.

## SCHEMATICS

Figure 10 represents a simplified schematic of one OP5330 module channel. It is composed of three stages: the first stage consists of one gain DAC and one offset DAC; the second stage consists of a signal DAC with an operational amplifier that allows for gain adjustments; the third stage consists of an operational amplifier that receives final signal value and integrates the offset.

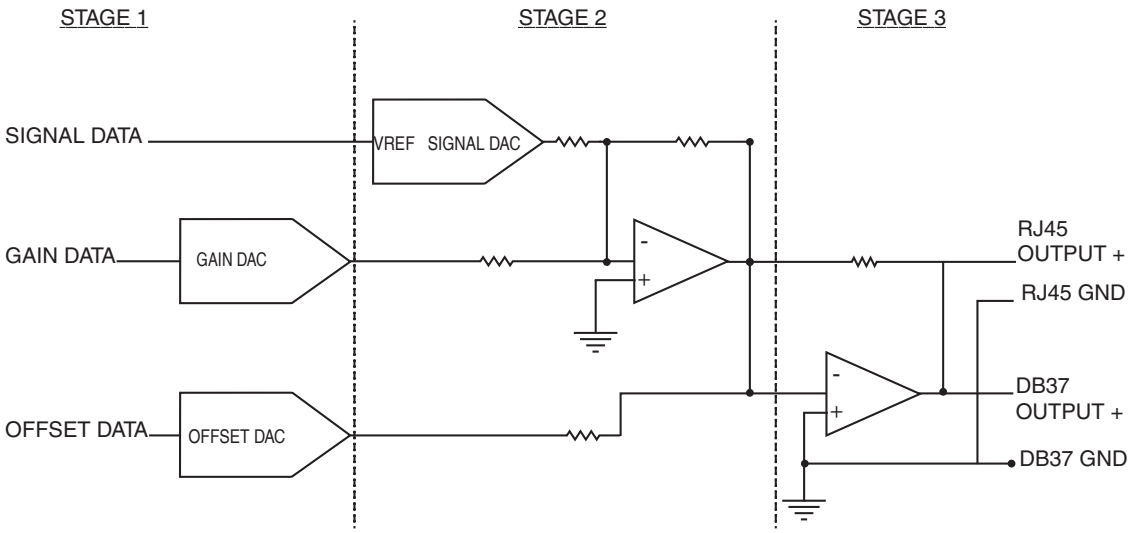



Figure 10: Output DAC circuit

## TYPICAL APPLICATIONS

The following diagram provides an example of a typical application using the OP5330.

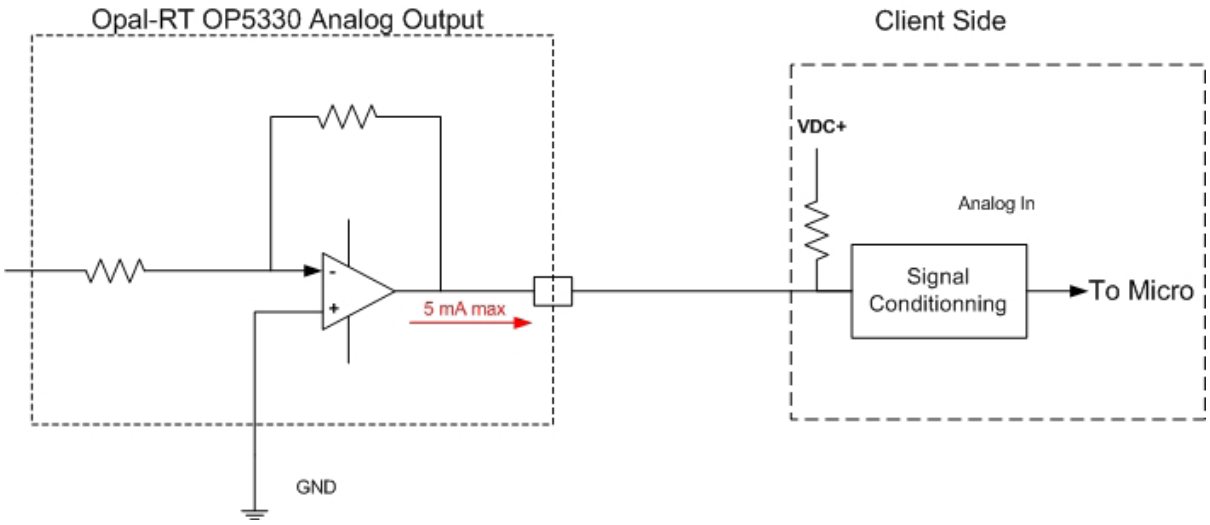



Figure 11: OP5330 typical application

# OP5340 ANALOG TO DIGITAL CONVERTER (0.5 MSPS)

## DESCRIPTION

The OP5340 Analog to Digital converter (ADC) is a part of the OP5000 series of optional modules for OPAL-RT's state of the art HIL (hardware-in-the-loop) systems, intended for use with OPAL-RT carrier boards (OP5130, OP5220, OP5222, OP5600, OP6228). Designed for OPAL-RT's simulation systems, the OP5340 converts analog signals to digital.

Each ADC can sample up to 500 kS/s, giving a total throughput of 8 MS/s, all channels are simultaneously sampled. The on-board EEPROM provides offset and gain data adjustment written during the calibration process, as well as over-voltage protection.

The OP5340 module provides 16 differential analog input channels. Each channel uses a 16-bit resolution analog-to-digital converter. The OP5340 module also has input signal conditioning capabilities that allow the user to apply a signal range from ±20v up to ±120v on the inputs. By default, the maximum input signal is set to ±20 volts.

#### REQUIREMENTS

**Software**

- RT-LAB 8.4.0 and higher

**Hardware**

- OPAL-RT simulator:
  - OP5000 series hardware-in-the-loop simulator
  - OPAL-RT I/O expansion box (only for use with OPAL-RT simulators)
- OPAL-RT carrier board:
  - OP5130, OP5220, OP5222, OP5600, OP6228

#### FEATURES

- 16 differential analog input channels
- All inputs are sampled simultaneously at up to 500 kSPS
- 16 bit resolution
- 500 KΩ input impedance
- ±20 V input voltage range
- ±240 input range up to 120V

#### OFFSET AND GAIN CALIBRATION

The OP5340 contains a serial EEPROM to store the module identification, calibration information and any other important information. Each OP5340 module is calibrated after assembly; during calibration, gain and offset are adjusted to ensure accurate target output values at ±20 mV noise and offset.

# SCHEMATICS

Figure 12 represents a simplified schematic of one OP5340 module channel. It is composed of three stages: the first stage consists of one operational amplifier that works in differential input mode and permits gain adjustment; the second stage, the level shifter, forms the signal for the A/D converter input; the third stage occurs after the conversion to the digital type, as the signal is sent to the carrier board.

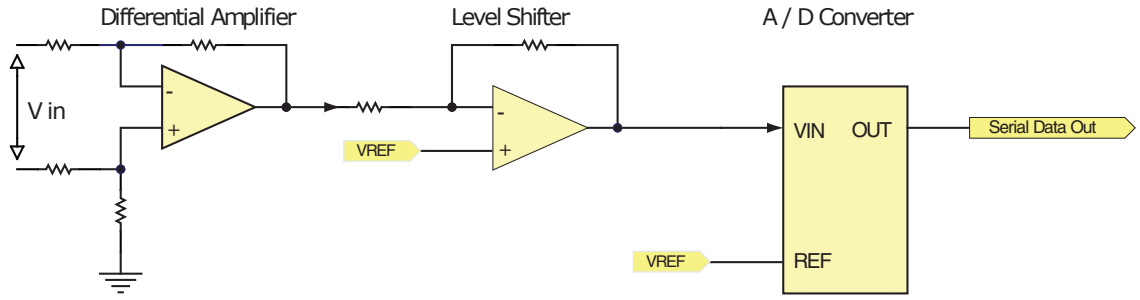
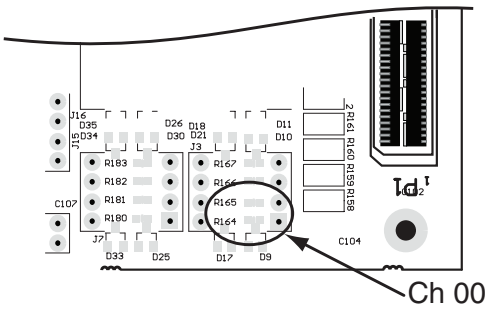



Figure 12: Differential input ADC circuit

### INPUT GAIN SELECTION

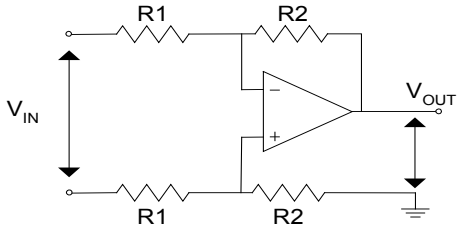



Optional - for advanced users.

The OP5340 module has user selectable input attenuation ability. By default, the maximum input voltage range is set to ±20 volts but each channel can be changed separately up to ±120 volts. The OP5340 module contains resistor networks that allow insertion of additional precision resistors to change the input attenuation. The image on the right shows the placement for the additional resistors.

Please refer to the table at the end of this section for the exact relationship between channels and resistors.

sThe next diagram illustrates the input stage of one channel. The default values for resistors R1 and R2 were chosen to keep the maximum input voltage range of ±20 volts (40 volts) with no additional resistors.

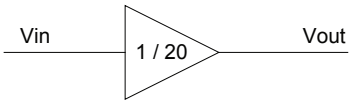



Vin full range = ±20 volts
Vout full range = ±1 volt (2 volts)
Installed resistors: **R1** = 499 kΩ
**R2** = 25 kΩ

Vout Formula

$$Vout = \left(\frac{R2}{R1}\right) Vin$$

The factory installed surface mount resistors on the OP5340 module give an attenuation of 20.



**INPUT GAIN CALCULATIONS**

The figures below show the complete circuit with resistor Rx as the axial insertable resistor by the user.

Input Gain Schematic with Rx

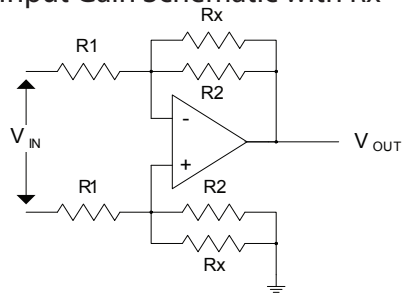



Figure 13: Input gain with Rx

Vout Formula with Rx

$$Vout = \left(\frac{R2}{R1}\right)\left(\frac{Rx}{R2 + Rx}\right)Vin$$

Vout Formula, with Default R Values and Rx
R1= 499K, R2= 25K

$$Vout = \frac{1}{20}\left(\frac{Rx}{25 + Rx}\right)Vin$$

Figure 14: Vout formulas

Users may define the input gain value and calculate the corresponding Rx resistor value.

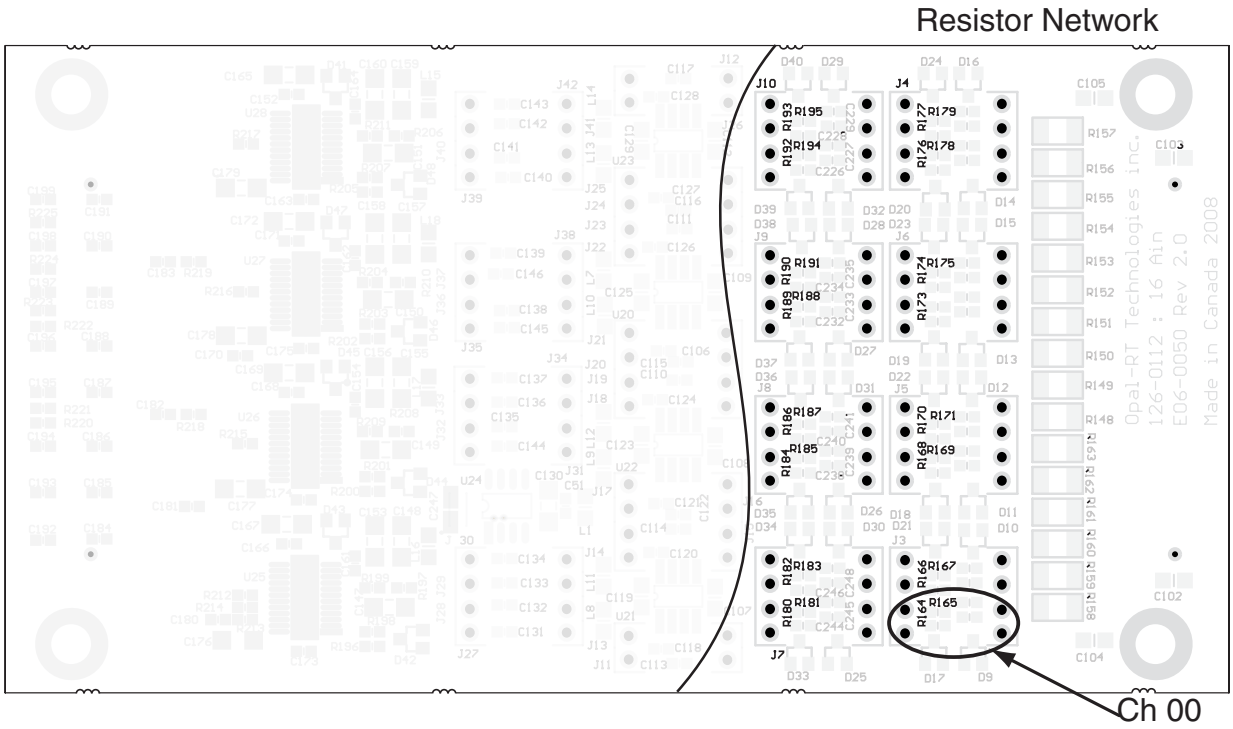
Table 2 provides maximum range values and associated Rx resistor values (chosen in 0.1% series range). To yield the same unit of measurement, the model must compensate for any new gain value different from the original gain of 1/20. The last column provides the gain to insert in the input signal of the simulation model.

| Input gain | Max voltage input | Rx value 0.1% series range | Gain to insert in the model |
|---|---|---|---|
| 1/20 | ±20V (or 40V) | none | 1 |
| 1/40 | ±40V (or 80V) | 24.9 kΩ | 2 |
| 1/60 | ±60V (or 120V) | 12.4 kΩ | 3 |
| 1/80 | ±80V (or 160V) | 8.25 kΩ | 4 |
| 1/100 | ±100V (or 200V) | 6.20 kΩ | 5 |
| 1/120 | ±120V (or 240V) | 4.99 kΩ | 6 |

Table 2: Maximum Range and Resistor Values

Example: an added Rx resistor of 4.99 kΩ in parallel with R2 resistor gives an attenuation of approximately 120 so the input voltage can be increased to ±120 volts (or 240 volts).

Table 3 shows the relationship between channel and resistor references used for the input gain changes.




| Channel # | Resistor Rx | Channel # | Resistor Rx |
|---|---|---|---|
| Channel 00 | R164, R165 | Channel 08 | R172, R173 |
| Channel 01 | R180, R181 | Channel 09 | R188, R189 |
| Channel 02 | R166, R167 | Channel 10 | R174, R175 |
| Channel 03 | R182, R183 | Channel 11 | R190, R191 |
| Channel 04 | R168, R169 | Channel 12 | R176, R177 |
| Channel 05 | R184, R185 | Channel 13 | R192, R194 |
| Channel 06 | R170, R171 | Channel 14 | R178, R179 |
| Channel 07 | R186, R187 | Channel 15 | R193, R195 |

Table 3: Resistor Network Channel Identification

# OP5341 ANALOG TO DIGITAL CONVERTER (2 MSPS)

## DESCRIPTION

The OP5341 is a part of the OP5000 series of optional modules for OPAL-RT's state of the art HIL (hardware-in-the-loop) systems, intended for use with with OPAL-RT carrier boards (OP5130, OP5220, OP5222, OP5600, OP6228). Designed for OPAL-RT's simulation systems, the OP5341 converts analog signals to digital.

Each ADC can sample up to 2 MSPS, giving a total throughput of 32 MS/s, all channels are simultaneously sampled. The on-board EEPROM provides offset and gain data adjustment written during the factory calibration process.

The OP5341 provides 16 differential analog input channels. Each channel uses a 14-bit resolution analog-to-digital converter. The OP5341 module also has input signal conditioning capabilities that allow the user to apply a signal range from ±20v up to ±120v on the inputs. By default, the maximum input signal is factory configured to ±20 volts.

#### REQUIREMENTS

**Software**

- RT-LAB 8.4.0 and higher

**Hardware**

- OPAL-RT simulator:
  - OP5000 series hardware-in-the-loop simulator
  - OPAL-RT I/O expansion box (only for use with OPAL-RT simulators)
- OPAL-RT carrier board:
  - OP5130, OP5220, OP5222, OP5600, OP6228

## FEATURES

- 16 differential analog input channels, 14 bits, 2 MSPS
- All inputs are sampled simultaneously at up to 2 MSPS
- 500 KΩ input impedance
- ±20 V input voltage range
- ±240 input range up to 120V

#### OFFSET CALIBRATION

The OP5341 contains a serial EEPROM to store the module identification, calibration information and any other important information. Each OP5341 module is calibrated after assembly; during calibration, gain and offset are adjusted to ensure accurate target Input values at ±20 mV noise (including gain and offset errors).

# SCHEMATICS

Figure 15 represents a simplified schematic of one channel of the OP5341 modules. It is composed of three stages: the first stage consists of one operational amplifier that works in differential input mode and permits gain adjustment; the second stage, the level shifter, forms the signal for the A/D converter input; the third stage occurs after the conversion to the digital type, as the signal is sent to the carrier board.

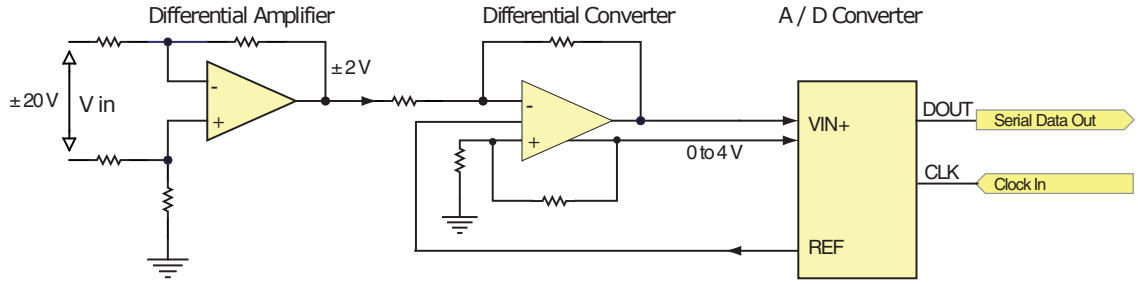
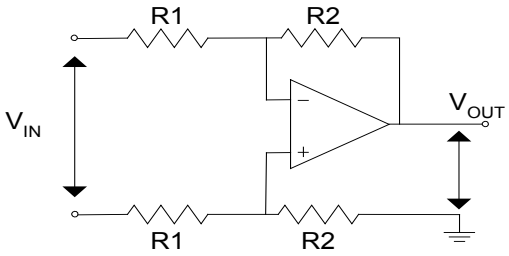



Figure 15: Differential input ADC circuit

The next diagram illustrates the input stage of one channel. The default values for resistors R1 and R2 were chosen to keep the maximum input voltage range of ±20 volts (40 volts) with no additional resistors.

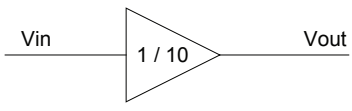



Vin full range = ±20 volts
VIN full range = ±2 volt (4 volts)
Installed resistors: **R1** = 499 kΩ
**R2** = 49.9 kΩ

Vout Formula

$$Vout = \left(\frac{R2}{R1}\right) Vin$$

The factory installed surface mount resistors on the OP5341 module give an attenuation of 10.



### INPUT GAIN CALCULATIONS

The figures below show the complete circuit with resistor Rx as a surface mount resistor.

Input Gain Schematic with Rx

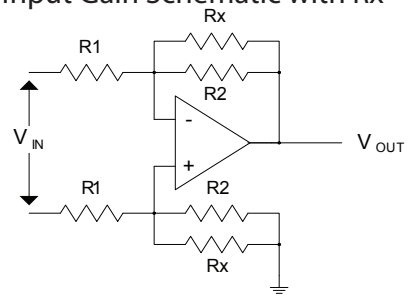



Figure 16: Input gain with Rx

Vout Formula with Rx

$$Vout = \left(\frac{R2}{R1}\right)\left(\frac{Rx}{R2+Rx}\right)Vin$$

Vout Formula, with Default R Values and Rx
R1= 499K, R2= 49.9K

$$Vout = \frac{1}{10}\left(\frac{Rx}{49.9+Rx}\right)Vin$$

Figure 17: VIN formulas

Users may define the input gain value and calculate the corresponding Rx resistor value.

Table 4 provides maximum range values. To yield the same unit of measurement, the model must compensate for any new gain value different from the original gain of 1/20. The last column provides the gain to insert in the input signal of the simulation model.

| Input Gain | Max Voltage Input | Gain to insert in the model |
|---|---|---|
| 1/10 | ±20V (or 40V) | .5 |
| 1/20 | ±40V (or 80V) | 1 |
| 1/30 | ±60V (or 120V) | 1.5 |
| 1/60 | ±80V (or 160V) | 2 |
| 1/50 | ±100V (or 200V) | 2.5 |
| 1/60 | ±120V (or 240V) | 3 |

Table 4: Maximum range values

# OP5353 32 DIN SIGNAL CONDITIONING MODULE

## DESCRIPTION

The OP5353 is a part of the OP5000 series of optional, versatile signal conditioning modules for OPAL-RT's state of the art HIL (hardware-in-the-loop) systems. Designed for OPAL-RT's simulation systems, the OP5353 provides digital input signals with specific voltage conditioning. The optical isolation of the OP5353 inputs make it ideal for environments where voltage isolation is required.

The OP5353 features 32 optically isolated input channels. All are sampled simultaneously for additional simulation accuracy. It is perfectly suited to interface real life environment signals to TTL or differential levels for RT-LAB simulator, providing perfect electrical isolation and discharge protection.

#### REQUIREMENTS

**Software**

- RT-LAB 8.4.0 and higher

**Hardware**

- OP5600 HILbox simulator
- OP5620 carrier board.

#### FEATURES

- 32 optically isolated input channels.
- All inputs are sampled simultaneously, at up to 10 MSPS.
- Inputs are read in parallel for any size bus simulation.
- Hardware configurable filters, and conditioning inputs for customization.
- Choice of sink or source inputs connection (anode and cathode side available).
- Minimum current input of 3.6 mA.
- 4V to 100V input voltage range.
- 30V maximum reverse protection

## INTERFACES

### Inputs

The optically isolated inputs accept a wide input voltage range, from 4 to 100 Volts, according to user requirements. They have a low threshold current; typically 3.6 mA.

Each input has a reverse voltage protection of up to 30 volts provided by a diode.

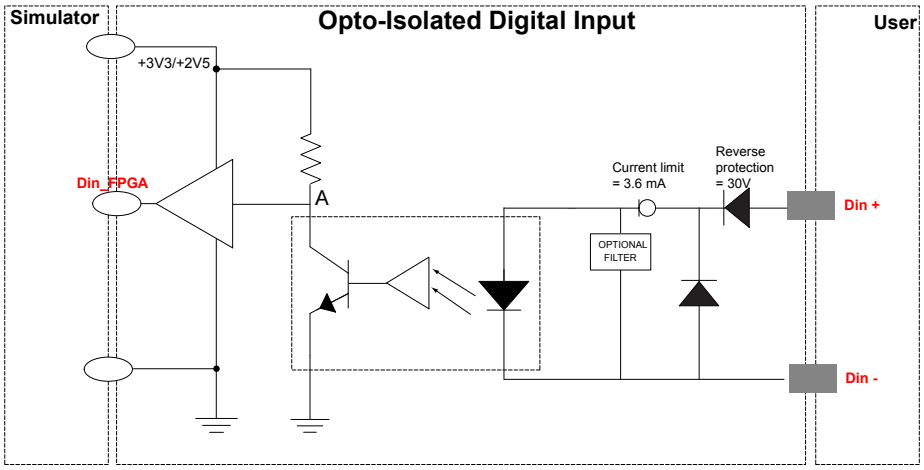



Figure 18: OP5353 Isolated digital input drawing

The signal conditioning module inputs have both anode and cathode sides available to the user (on the I/O connector).

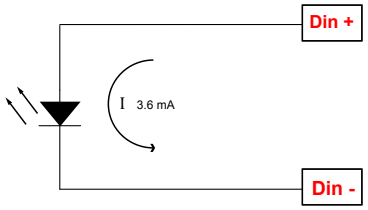



Figure 19: Both Din + and Din - are available to the user

When current flows from Din+ to Din -, the output of opto-coupler A is **low** and the Din_FPGA signal is **low.**

When no current flows, the opto-coupler output A is **high** and the Din_FPGA signal is **high.**

**POWER CONFIGURATION**

The digital input circuit needs a 5 V supply source to power the onboard circuitry. This source is connected to the computer's 5 VDC.

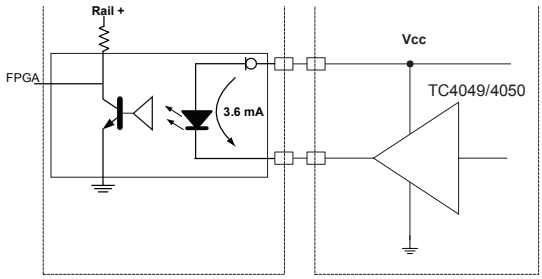



Figure 20: Typical digital input circuit

To work properly, the OPAL-RT digital input optical isolator needs a typical current of 3.6 mA.

# TYPICAL APPLICATIONS

The diagrams below illustrate typical application examples.

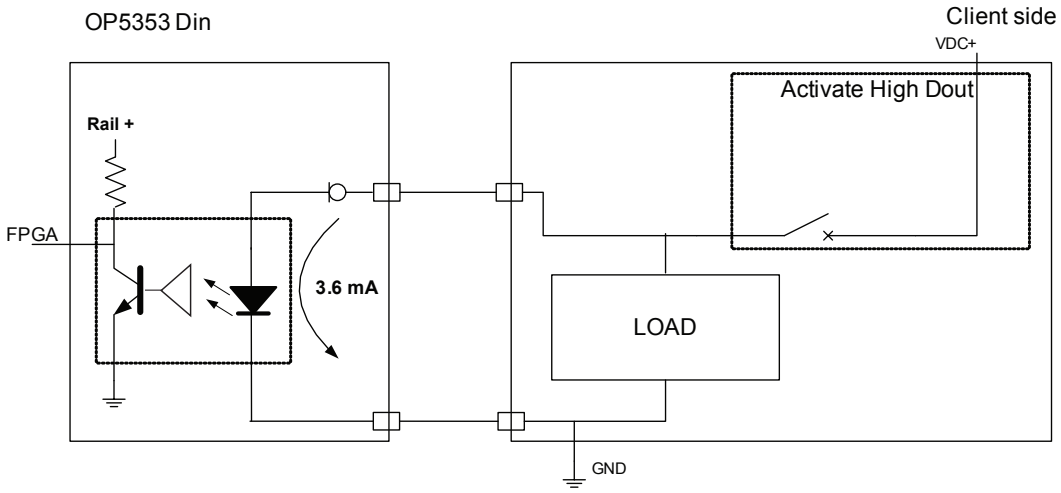



Figure 21: Typical high side activation (user high Dout)

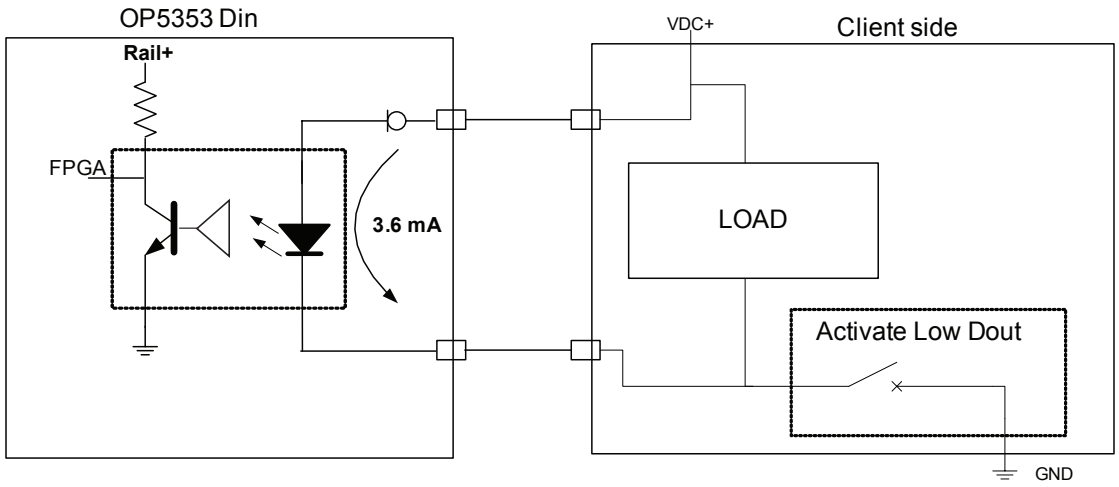



Figure 22: Typical low side activation (user low Dout)

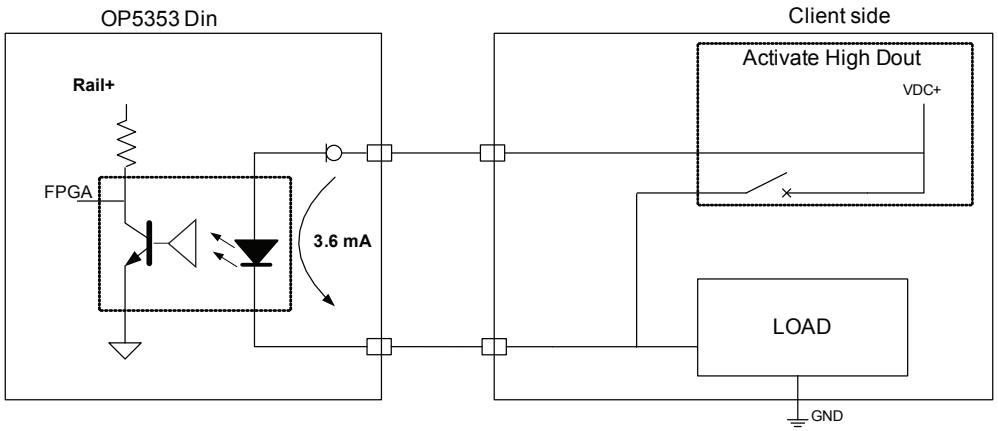



Figure 23: Typical high side open circuit detection

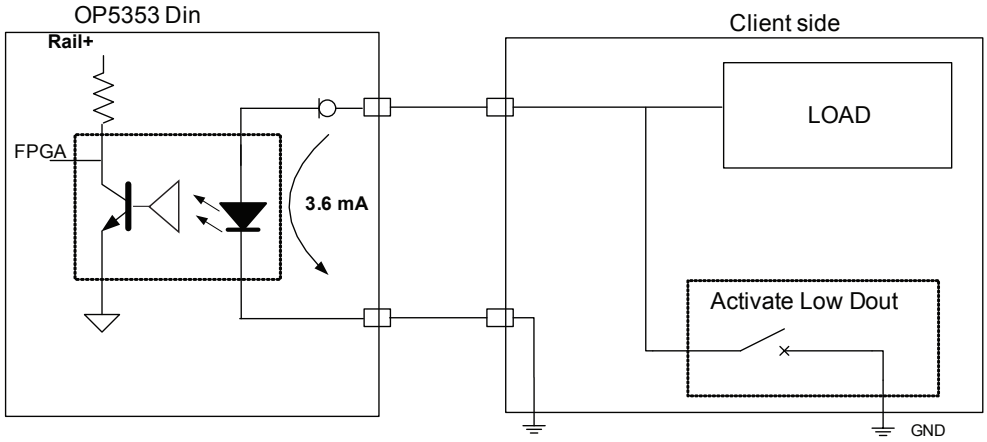



Figure 24: Typical low side open circuit detection

# OP5354 32 DOUT SIGNAL CONDITIONING MODULE

## DESCRIPTION

The OP5354 is a part of the OP5000 series of optional, versatile Signal Conditioning Modules for OPAL-RT's state of the art HIL (hardware-in-the-loop) systems. Designed for OPAL-RT's simulation systems, the OP5354 provides digital output signals with specific voltage conditioning. The galvanic isolation of the OP5354 outputs make it ideal for environments where voltage isolation is required.

The OP5354 features 16 or 32 galvanically isolated output channels and all are outputted simultaneously. It is perfectly suited to interface TTL or differential signals to real-life environment signals, providing perfect electrical isolation with full short-circuit protection.

#### REQUIREMENTS

**Software**

- RT-LAB 8.4.0 and higher

**Hardware**

- OP5600 and OP7000 simulators.
- OPAL-RT OP5620 and OP7220 carrier boards.

#### FEATURES

- 32 galvanically isolated output channels
- All outputs are outputted simultaneously, at up to 40 MSPS.
- Short-circuit protected by auto-resettable fuse.
- Outputs stage is a Push-Pull type circuit
- All outputs accept voltage of 5 to 30V and the output current is up to ±50mA.
- Voltage supplied by user side.

## OUTPUTS

Each galvanically isolated output has a push-pull transistor. It can sink up to 50 mA continuous, and up to +30V according to user requirements. It is current protected by resettable 150 mA fuse (PTC). The galvanic isolation circuitry is powered by an internal isolated DC supply.

**CAUTION: If Vuser is connected to the simulator, the output voltage DOUT would be the same as Vuser as long as no RT-LAB model is running (output transistor is open).**

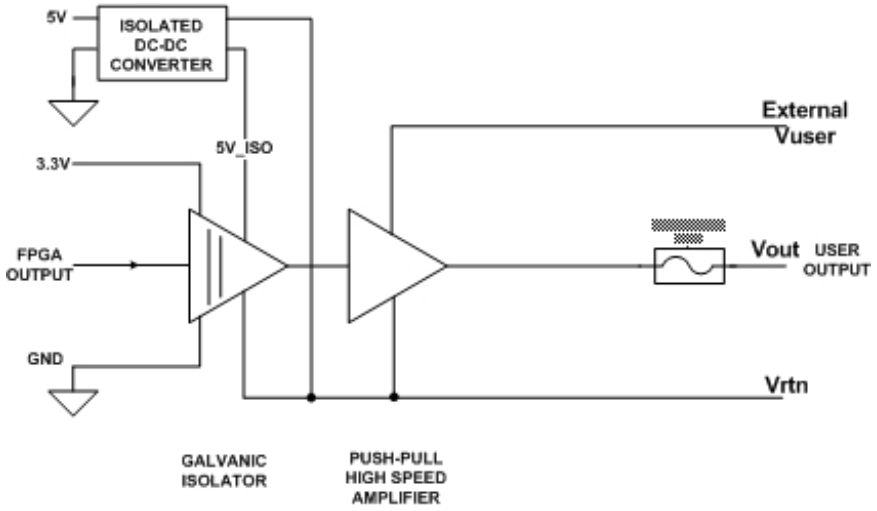



Figure 25: Isolated digital output schematic

NOTE: Vrtn is normally the Vuser_GND.

# TYPICAL APPLICATION

The diagram below illustrates typical application examples.

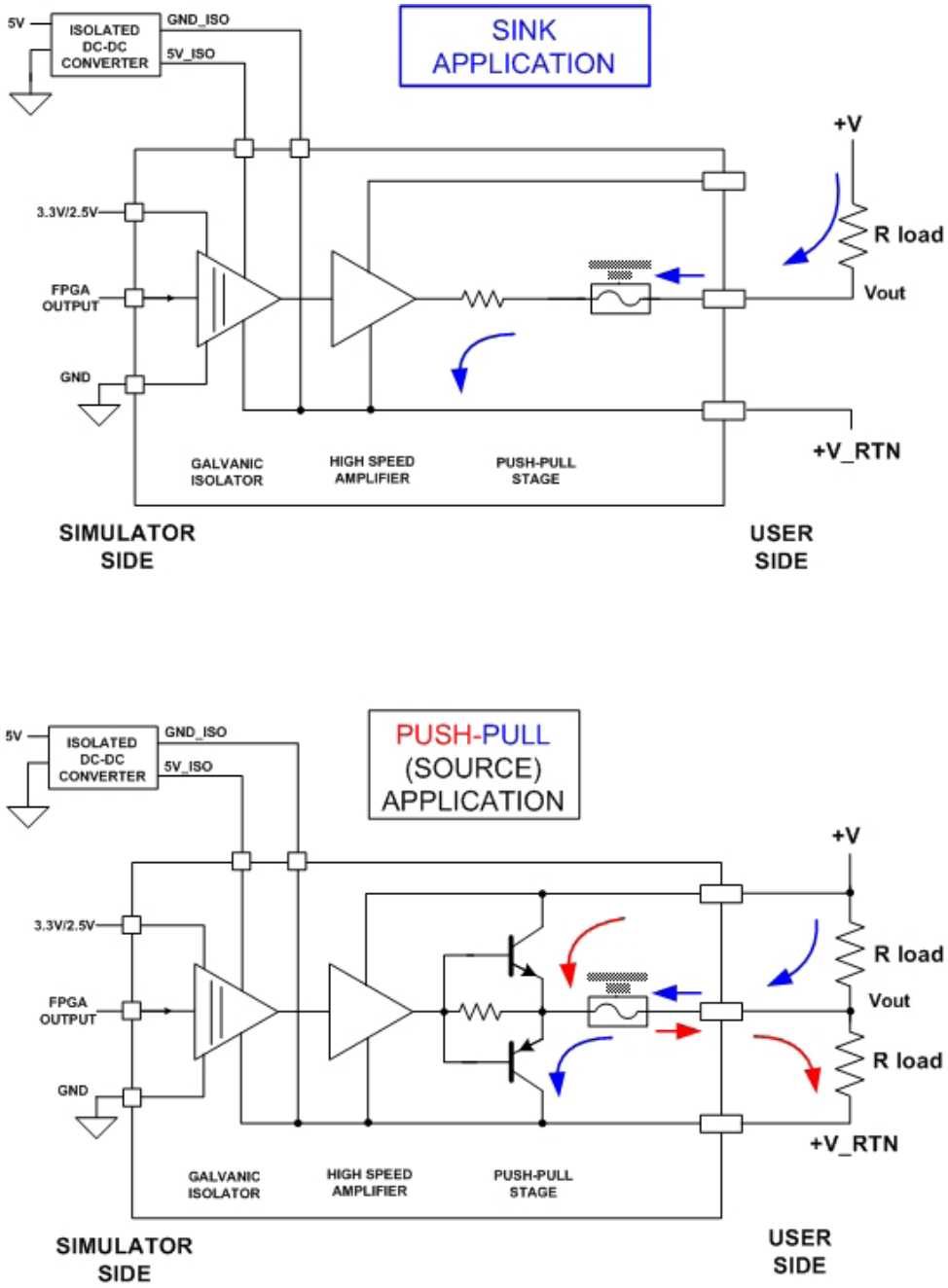



Figure 26: OP5354 Typical source (push-pull) application

# SPECIFICATIONS

## OP5600 SIMULATOR SPECIFICATIONS

| **Product name** | **OP5600 HIL Box** | |
|---|---|---|
| Power supply | Universal input and active power factor correction 650W continuous power<br>DC to DC converters for analog voltage | |
| I/O connectors | Spartan 3:<br>4 panels of 4 DB37F connectors | Virtex 6:<br>3 panels of 4 DB37F connectors |
| Monitoring connectors | Spartan 3:<br>4 panels of RJ45 connectors | Virtex 6:<br>3 panels of RJ45 connectors |
| PC interface | Standard PC connectors (monitor, keyboard, mouse and network) | |
| PCI slots | 2 PCI<br>4 PCIe | |
| Carrier board | Spartan 3 configuration: 8 mezzanines<br>Virtex 6 configuration: 6 mezzanines | |
| Hard disk | 250 Gb, 7200 rpm, SATA | |
| Dimensions | 48.3 x 45.7 x 17.8cm (19” x 18” x 7”) WxDxH | |
| Weight | With PC: 9.07 - 11.34 Kg (20 lbs to 25 lbs)<br>Without PC: 4.54 x 5.9 Kg (10 lbs to 13 lbs) | |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) | |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) | |
| Relative humidity | 10 to 90% non-condensing | |
| Maximum altitude | 2000 m (6562 ft.) | |

# OP5330 DIGITAL TO ANALOG CONVERTER SPECIFICATIONS

| **Product Name** | **OP5330** |
|---|---|
| Part Number | 126-0157 |
| Number of channels | 16 single-ended |
| Resolution: | 16 bits |
| Default range | ± 15 Volts |
| Maximum current | 15 mA |
| Max. Sampling Frequency | 1 MS/s |
| Min Conversion / Acquisition Time | 1 µs per channel |
| DAC Type | 8 x Dual DAC with 50 MBit/s Serial Output Transfer |
| CMRR | 100 dB |
| Calibration | Programmable gain and offset calibration for each D/A. Calibration factors are stored in on-board non-volatile memory (EEPROM) |
| Maximum noise | 20 mV peak-to-peak |
| Recommended warm-up time | 5 min. |
| Calibration interval | as required |
| Dimensions | 6.60 cm x 12.50 cm (2.6” x 4.92”) |
| I/O connector: | 80-pin high speed header to carrier |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) |
| Relative humidity | 10 to 90%, non condensing |
| Maximum altitude | 2,000 m (6562 ft.) |

# OP5340 ANALOG TO DIGITAL CONVERTER (0.5 MSPS) SPECIFICATIONS

| **Product name** | **OP5340 (16 analog inputs - 500 KSPS)** | |
|---|---|---|
| Part number | 126-0112 | |
| Number of channels | 16 differentials | |
| Resolution | 16 bits | |
| Max. Sampling Frequency | 500 KSPS | |
| Min Conversion / Acquisition Time | 2.5 µs per channel | |
| ADC Type | 8 x Dual ADC with 10 MBit/s Serial Output Transfer | |
| **Nominal Input Ranges (V)** | **Positive Full Scale** | **Negative Full Scale** |
| | +120.0 | -120.0 |
| | +100.0 | -100.0 |
| | +80.0 | -80.0 |
| | +60.0 | -60.0 |
| | +40.0 | -40.0 |
| | +20.0 (Hardware default value) | -20.0 |
| No missing codes resolution | 14 bits min. | |
| Integral nonlinearity (INL) | ±8 LSB max. (Typical: ±3 LSB) | |
| Differential nonlinearity (DNL) | ±1.5 LSB typ. (0 to +70°C) | |
| CMRR | 90 dB | |
| Bandwidth | Small signal (-3 dB): 820 kHz | |
| | Large signal (0.1% THD): 55 kHz | |
| System noise | 1.8 LSB rms (including quantization) | |
| Calibration | Calibration factors are stored in on-board non-volatile memory (flash memory). This memory is not accessible for calibration.. | |
| Recommended warm-up time | 5 min. | |
| Calibration interval | as required | |
| Dimensions | 6.60 cm x 12.50 cm (2.6” x 4.92”) | |
| I/O connector | 80-pin high speed header to carrier | |
| **Environmental** | | |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) | |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) | |
| Relative humidity | 10 to 90%, non condensing | |
| Maximum altitude | 2,000 m (6562 ft.) | |

# OP5341 ANALOG TO DIGITAL CONVERTER (2 MSPS) SPECIFICATIONS

| **Product name** | **OP5341 (16 analog inputs - 2 MSPS)** | |
|---|---|---|
| Part number | 126-0301 | |
| Number of channels | 16 differentials | |
| Resolution | 14 bits | |
| Max. Sampling Frequency | 2 MSPS | |
| Min Conversion / Acquisition Time | 500 nanoseconds per channel | |
| ADC Type | 8 x Dual ADC with 40 MBit/s Serial Output Transfer | |
| **Nominal Input Ranges (V)** | **Positive Full Scale** | **Negative Full Scale** |
| | +120.0 | -120.0 |
| | +100.0 | -100.0 |
| | +80.0 | -80.0 |
| | +60.0 | -60.0 |
| | +40.0 | -40.0 |
| | +20.0 (Hardware default value) | -20.0 |
| Bandwidth | Small signal (-3 dB): 820 kHz | |
| | Large signal (0.1% THD): 55 kHz | |
| System noise | 1.8 LSB rms (including quantization) | |
| Calibration | Calibration factors are stored in on-board non-volatile memory (flash memory). This memory is not accessible for calibration.. | |
| Recommended warm-up time | 5 min. | |
| Calibration interval | as required | |
| Dimensions | 6.60 cm x 12.50 cm (2.6” x 4.92”) | |
| I/O connector | 80-pin high speed header to carrier | |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) | |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) | |
| Relative humidity | 10 to 90%, non condensing | |
| Maximum altitude | 2,000 m (6562 ft.) | |

# OP5353 32 DIN SPECIFICATIONS

| **Product name** | **OP5353 (32 opto-isolated digital inputs)** |
|---|---|
| Part number | 126-0312 |
| Number of channels | 32 digital inputs |
| Isolation | Optical isolator |
| Connection mode | Anode and cathode available on connector |
| Input current | 3.6 mA, current limiting diode |
| Reverse voltage protection | Schottky diode |
| Maximum reverse voltage protection | 30 Volts |
| Detection threshold | Separate Schmitt Trigger |
| Voltage range | 4 to 100 Vdc |
| Delay Low-to-High | 110 ns |
| Delay High-to-Low | 60 ns |
| Rise/Fall times | 6 ns/6 ns |
| Form factor | Mezzanine Type B |
| Dimensions | 6.60 cm x 12.50 cm (2.6” x 4.92”) |
| I/O connector | 80-pin high speed header to carrier |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) |
| Relative humidity | 10 to 90%, non condensing |
| Maximum altitude | 2,000 m (6562 ft.) |

# OP5354 DOUT SPECIFICATIONS

| **Product name** | **OP5354 (32 digital outputs - push-pull)** |
|---|---|
| Part number | 126-0314 |
| Number of channels | 32 digital outputs |
| Isolation | Galvanic isolator |
| Output Current max | ±50 mA continuous |
| Output Protection | 150 mA resettable fuse |
| Output Voltage range | 5 to 30 Vdc |
| Output configuration | Push-pull |
| Delay Low-to-High | 20 ns |
| Delay High-to-Low | 20 ns |
| Rise/Fall times | 6 / 6 ns |
| Power Isolation | On-board DC to DC isolated converter |
| Form factor | Mezzanine Type B |
| Dimensions | 6.60 cm x 12.50 cm (2.6” x 4.92”) |
| I/O connector | 80-pin high speed header to carrier |
| Operating temperature | 10 to 40 ºC (50 to 104ºF) |
| Storage temperature | -55 to 85ºC (-67 to 185ºF) |
| Relative humidity | 10 to 90%, non condensing |
| Maximum altitude | 2,000 m (6562 ft.) |

# LIMITED WARRANTY

**LIMITED WARRANTY**

oPAL-RT Technologies Inc. warrants to the original purchaser and/or ultimate customer (“Purchaser”) of OPAL-RT products (“Product”) that if any part thereof proves to be defective in material or workmanship within one (1) year, such defective part will be repaired or replaced, free of charge, at OPAL-RT Technologies’ discretion, if shipped prepaid to OPAL-RT Technologies Inc. at 1751 Richardson, suite 2525, Montreal, Quebec, Canada, H3K 3G6, in a package equal to or in the original container. The Product will be returned freight prepaid and repaired or replaced if it is determined by OPAL-RT Technologies Inc. that the part failed due to defective materials or workmanship. Otherwise, the fees will be charged to the client (see **“WARRANTY LIMITATION AND EXCLUSION”**). The repair or replacement of any such defective part shall be OPAL-RT Technologies’ sole and exclusive responsibility and liability under this limited warranty.

Purchaser must request an RMA number before shipping any Product for repair:

1. Access the OPAL-RT website (www.OPAL-RT.com/support/ return-merchandise-authorization-rma-request), click on support and select Return Merchandise (RMA).
2. Fill out the online form and submit. You will receive a notification with a thread-ID that will be used for further exchange with support.
3. OPAL-RT’s Support department will evaluate the return and either issue an RMA number via email using the same thread-ID.
   - If the Product is returned for repair more than 12 months after purchase, the Purchaser is responsible for the cost of repair. OPAL-RT will assess the repair and prepare a quote. The RMA number will be sent with the quote.
4. Only when the Purchaser receives the RMA number, may they ship the Product, prepaid, to OPAL-RT.

**RETURN POLICY**

The following fees will apply when customers return products for credit:

A full credit, less a 15% fee and less return fee will only be issued if the product is in perfect working condition and if the product is returned within 1 month following the shipping date. If repairs are required on the returned product, the cost of these repairs will be deducted from the credit to be issued.

No credits will be issued beyond the one month period.

**EXCLUSIONS**

If third party products are part of the Product, OPAL-RT will honor the original manufacturer’s warranty.

This limited warranty does not cover consumable items, such as batteries, or items subject to wear or periodic replacement, including lamps, fuses or filter elements.

### WARRANTY LIMITATION AND EXCLUSION

OPAL-RT Technologies will have no further obligation under this limited warranty. All warranty obligations of OPAL-RT Technologies are void if the Product has been subject to abuse, misuse, negligence, or accident or if the Purchaser fails to perform any of the duties set forth in this limited warranty or if the Product has not been operated in accordance with instructions, or if the Product serial number has been removed or altered.

### DISCLAIMER OF UNSTATED WARRANTIES

The warranty printed above is the only warranty applicable to this purchase. All other warranties, express or implied, including, but not limited to, the implied warranties of merchantability or fitness for a particular purpose are hereby disclaimed.

### LIMITATION OF LIABILITY

It is understood and agreed that OPAL-RT Technologies' liability, whether in contract, in tort, under any warranty, in negligence or otherwise shall not exceed the amount of the purchase price paid by the purchaser for the product and under no circumstances shall OPAL-RT Technologies be liable for special, indirect, or consequential damages. The price stated for the product is a consideration limiting OPAL-RT Technologies' liability. No action, regardless of form, arising out of the transactions under this warranty may be brought by the purchaser more than one year after the cause of actions has occurred.

**CONTACT**

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**While every effort has been made to ensure accuracy in this publication, no responsibility can be accepted for errors or omissions. Data may change, as well as legislation, and you are strongly advised to obtain copies of the most recently issued regulations, standards, and guidelines.**
**This publication is not intended to form the basis of a contract.**

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